

Parvodinium gen. nov. for the Umbonatum Group of *Peridinium* (Dinophyceae)

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ABSTRACT: *Peridinium* is a genus of freshwater thecate dinoflagellate. Because it was one of the earliest named genera (Ehrenberg 1832), many species placed in it were later removed to other genera. Genera continue to be extracted and *Peridinium*, while more closely defined, still harbors groups of species unlike the type species, *P. cinctum*. It is the goal of this paper to remove one of the most dissimilar groups, the Umbonatum Group. *Peridinium cinctum* has no apical pore, three apical intercalary plates and five cingular plates. Species in the Umbonatum Group have an apical pore, two apical intercalary plates and six cingular plates warranting their separation into a new genus, *Parvodinium*.

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INTRODUCTION

Freshwater dinoflagellates are a group of algae found mostly in open water habitats. As members of the phytoplankton they are food for zooplankton and may form blooms during the temperate summer. Most are recognizable as dinoflagellates by their golden brown color and shape, but further taxonomic identity may be challenging. Many reports of dinoflagellates, as part of a list of taxa, include only "*Peridinium* sp." The genus *Peridinium* was originally established for cells with a cell wall divided into plates and with a transverse groove (Fig. 1), and was distinguished from a similar genus (*Glenodinium*) by the absence of an eyespot (Ehrenberg 1830, 1838). Stein (1883) refined the description by illustrating the plate tabulation pattern of *P. cinctum* (O.F.Müller) Ehrenberg, the type species (Fig. 2). It has long been recognized that species in *Peridinium* showed a great deal of variability. Thecate dinoflagellate taxa are primarily defined by the number and arrangement of plates in the epitheca, hypotheca, sulcus and cingulum, the latter three considered more conservative (Balech 1980). Balech (1974) used differences in the number and shape of cingular plates to separate *Protoperidinium* from *Peridinium*, and other taxa first described as species of *Peridinium* have been moved to other genera including *Gymnodinium*, *Gonyaulax*, *Ceratium*, *Thompsodinium* and *Glochidinium* based on differences from the plate pattern of *P. cinctum*. *Peridinium* has come to be defined as having a plate formula of 4' 2-3a, 7'', 5''' 2''''', with species based on the presence/absence of an apical pore, the two alternatives for number of apical intercalary plates, plate arrangements, size, ornamentation, and nutrition (photosynthetic or heterotrophic). *Peridinium* species have long been organized into groups based these features. Lemmermann (1910) had a section *Poroperidinium* (with an apical pore) and *Cleistoperidinium* (without), Lindemann (1918) had Gruppe: *Peridinium willei*, and Gruppe: *Peridinium cinctum*, in addition to species in *Poroperidinium*. Lefèvre's monograph (1932) divided *Peridinium* into subgenus *Cleistoperidinium* (with Groupes Willei, Striolatum, Cinctum, and Palatinum) and subgenus *Poroperidinium* (with Groupes Bipes, Gutwinskii, Umbonatum, Elpatiewskii, Cunninghamii, Lindemanni, Penardi, Lomnickii, Godlewskii, Allorgei, and Polonicum). Many of the species groups in *Poroperidinium* are now in the genus *Peridiniopsis* (3-5', 0-1a, 6-8'', 5''', 2''''') (Bourrelly 1968). Popovský and Pfister (1990) continued dividing *Peridinium* into two subgenera *Poroperidinium* and *Cleistoperidinium* with the same four sections in *Cleistoperidinium* and five sections in *Poroperidinium*. Groupe Cinctum, in subgenus

Cleistoperidinium, includes the type species, *Peridinium cinctum* (O.F.Müller) Ehrenberg, which lacks an apical pore and has three apical intercalary plates in an asymmetrical arrangement. It has been suggested that all species differing from the type species should not be considered *Peridinium* (Fensome and others 1993). Groupe Umbonatum, in subgenus *Poroperidinium*, has an apical pore and two apical intercalary plates. Examination of these and other features contrasting the species in the Umbonatum Group with *Peridinium cinctum* provides sufficient morphological evidence to remove them from *Peridinium* and place them into a new genus. The genus *Parvodinium* gen. nov. is proposed to accommodate one obviously distinct group from the genus *Peridinium*.

MATERIALS AND METHODS

Samples have been collected from the United States, Belize and Ecuador. I have collected *Peridinium cinctum* twice, and only its forms; form *meandricum* Lefèvre from Texas and form *tuberosum* (Meunier) Lindemann from Ohio. *Peridinium gatunense* Nygaard, which has the same plate pattern and can be mistaken for *P. cinctum* (Hickel and Pollinger 1988), is common and has been collected from Michigan (MI), Minnesota (MN), North Carolina (NC), Ohio (OH), Texas (TX), Washington (WA), and Wisconsin (WI). *Peridinium umbonatum* has been collected from Florida (FL), NC, OH, TX, WA, *P. africanum* from TX, *P. belizensis* from Belize, *P. centenniale* from Belize, *P. inconspicuum* from TX, OH, WA, MI, WI and Wyoming and *P. gosaviense* from OH. Plate designation follows Kofoed (1909). Plate details have been reconstructed from scanning electron microscope (SEM) images taken with a Hitachi S-2700.

RESULTS AND DISCUSSION

Peridinium cinctum has a plate pattern of four apical, three apical intercalary and seven precingular plates in the epitheca, there is no apical pore, the 1' plate does not reach the apex, the 3' plate is topmost, the 2' plate is moderately sized, the 3' and 4' are large (Fig. 3a-c). The apical intercalary plates are described as asymmetrical (to contrast with the symmetrical apical plates of the Willei Group), there is a small, pentagonal 1a, larger 2a, and large 3a plate (Fig. 3c). In dorsal view, the 4'' plate is central and five sided, the 2a and 3a plates both touching it (Fig. 3b). Antapical plates are about equal in size (Fig. 3d). There are five cingular plates aligned with the postcingulars (Fig. 1e) and five sulcal plates (Fig. 3f). Thecal plates are thick, frequently have reticulate ornamentation, and cells are large, 40-64µm diameter (Table 1).

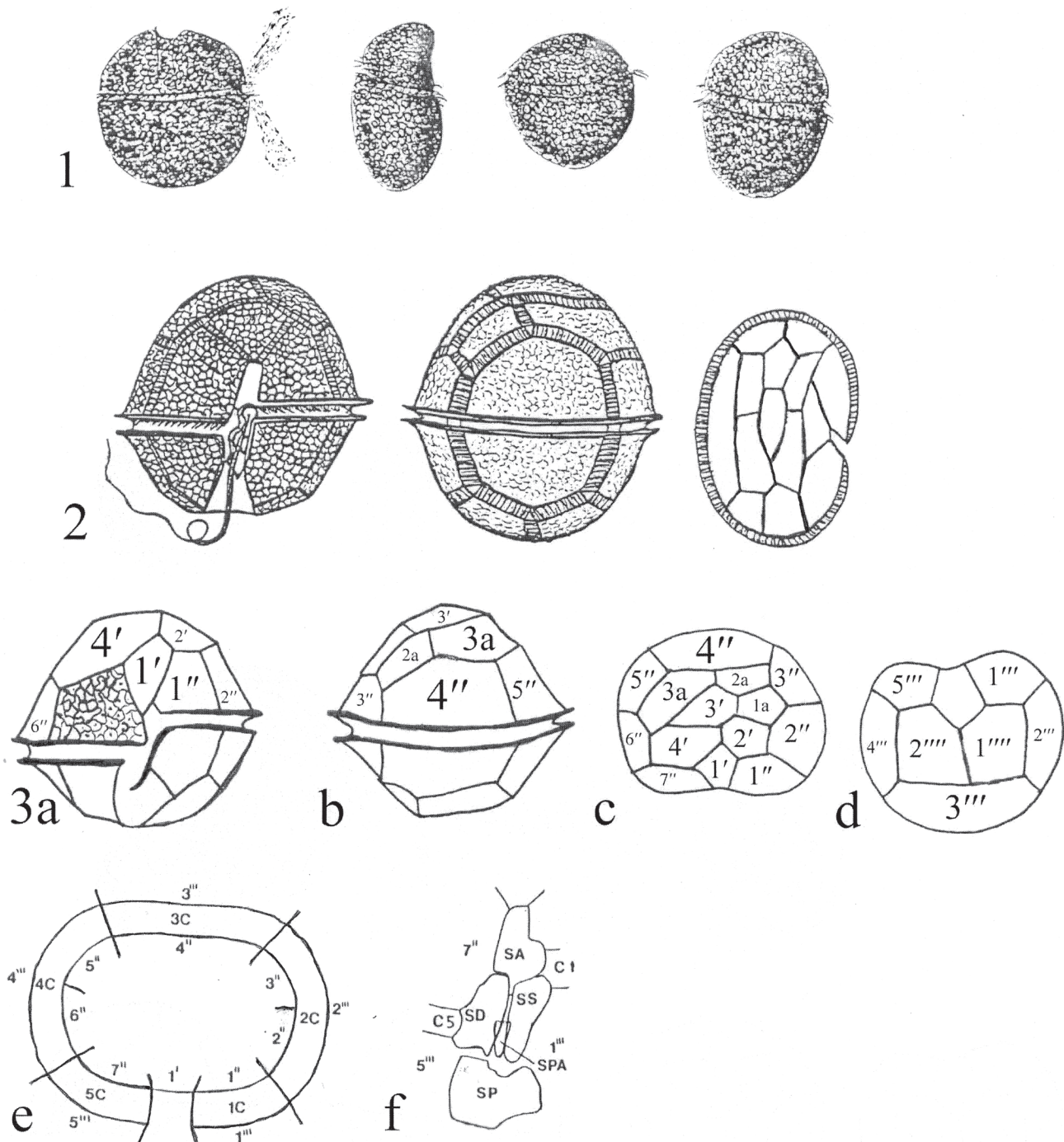
The Cinctum group contains two species besides *P. cinctum*, they share the asymmetry of the apical plates and differ in overall shape.

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Peridinium gatunense Nygaard is spherical with no dorsoventral compression, has wide cingular lists and a small first apical plate. *Peridinium vaciborskii* Wołoszynska is large (70-80µm), and strongly dorsoventrally compressed. *Peridinium cinctum* has some named variations.

Peridinium umbonatum Stein (Fig. 4-5) has a plate pattern of four apical, two apical intercalary and seven precingular plates in the epitheca, there is an apical pore covered by a cover plate and surrounded by a pore plate, and a canal plate runs ventrally to the apex of the 1' plate (Figs. 5a-c, 6, 8). Antapical plates are about

equal in size (Fig. 5d). The six cingular plates are not neatly aligned with pre- or postcingular plates except for the mid dorsal alignment of all three (Fig. 5e). Sulcal plates differ individually from their counterparts in *P. cinctum*, especially the Sd in *P. umbonatum* which forms a distinctive flap over the flagellar pore (Figs. 5f, 6). On the dorsal surface the two apical intercalary plates, and the 3' and 4'' plates have a plastic relationship, *conjunctum* when the 3' and 4'' share a suture and 1a and 2a are separated (Figs. 5b, c, 7, 8, and in original Stein drawings Fig. 4), *contactum* when all four plates meet (Fig. 5g), and *remotum* when 1a and 2a share a suture and 3' and



FIGURES 1-3. Line drawings. Fig. 1. Original drawing from Ehrenberg 1830. Fig. 2. Diagram from Stein (1883) showing plates. Fig. 3a. Ventral view, one plate showing reticulate ornamentation. Fig. 3b. Dorsal view, plates numbered using Kofoidian system. Fig. 3c. Apical view with plates identified, note asymmetrical arrangement of apical and apical intercalary plates. Fig. 3d. Antapical view. Fig. 3e. Cingular plates with sutures in relation to sutures of pre- and postcingular plates (after Carty 1986). Fig. 3f. Sulcal plates (after Boltovskoy 1975).

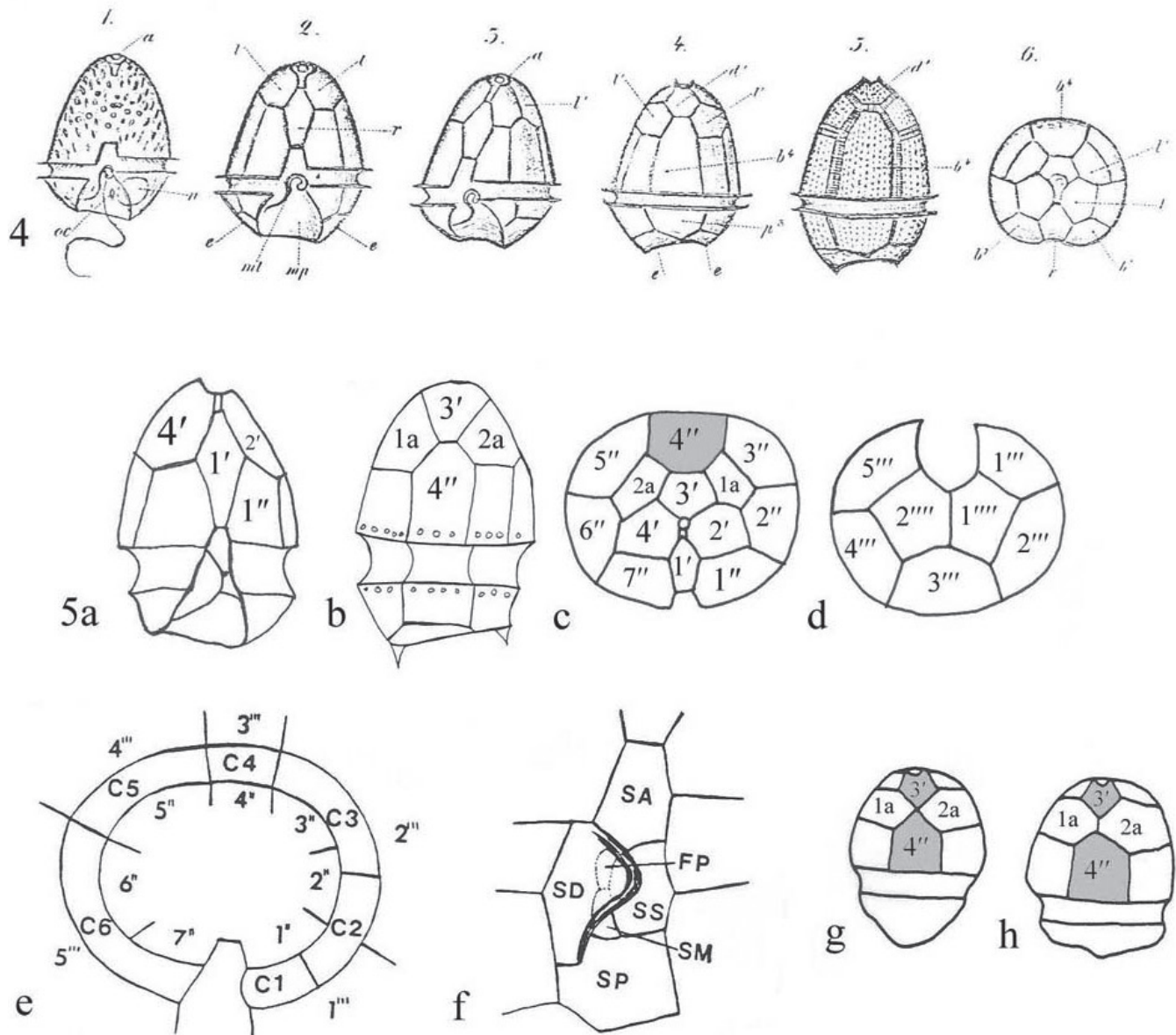
4'' are separated (Fig. 5h) (Lefèvre 1932). Lefèvre (1932) included the dorsal plate arrangement (ie *Peridinium umbonatum* tab. *conjunctum*) as part of the species name. Work on clonal isolates shows all three forms may appear, though 94% were *conjunctum*, and that in natural populations either *conjunctum* or *remotum* may predominate (Elbrächter and Meyer 2001). Plate fluidity is characteristic of some taxa like the species in the Umbonatum Group, *Thomposodinium* (Carty 1989), and *Durinskia* (Chesnick and Cox 1985). In the Umbonatum Group thecal plates are thinner than in the Cinctum group, there are various types of ornamentation, cells are small (12-20µm diameter), and forms/varieties often have spines (Table 1).

Species within the Umbonatum group are distinguished by overall shape, presence of spines, and plate sizes and positions. Popovský and Pfister (1986, 1990) synonymized many species with *P. umbonatum* (retaining *P. morzinense* and *P. africanum*) as varieties (var. *centenniale*, var. *deflandrei*, var. *goslaviense*, var.

lubieniense and var. *umbonatum*). Much of the perceived overlap among the species can be eliminated by reference to original descriptions and illustrations.

Sexual reproduction has been investigated in *P. cinctum* (Pfister 1975) and *P. inconspicuum* in the Umbonatum Group (Pfister and others 1984). While there are many similarities, *P. inconspicuum* was unique among *Peridinium* species in having the gamete protoplasts leave their thecae and fuse in the middle (Pfister and others 1984).

Molecular analyses of species using small subunit (SSU) ribosomal RNA generates phylogenetic trees that show some clades of *Peridinium* species (*P. volzii*, *P. willei*, *P. bipes*) distant from "*Peridinium*" *umbonatum* (Saldarriaga and others 2004). A more extensive phylogenetic analysis using both SSU and large subunit (LSU) data, and focused on freshwater species, also found a group of *Peridinium* species (*P. cinctum*, *P. bipes*, *P. gatunense*, *P. volzii*, *P. willei*) separated from Umbonatum group species (*umbonatum*, *inconspicuum*, *centenniale*) (Logares and others 2007). These two



FIGURES 4 AND 5. Line drawings. Fig. 4 Original drawing from Stein 1883. Fig. 5a. Ventral view. Fig. 5b. Dorsal view, 3' and 4'' *conjunctum*. Fig. 5c. Apical view with plates identified, 3' and 4'' *conjunctum*. Fig. 5d. Antapical view. Fig. 5e. Cingular plates with sutures in relation to sutures of pre- and postcingular plates (after Carty 1986). Fig. 5f. Sulcal plates, note Sd forming flap over flagellar pore (FP) (after Carty 1986). Fig 5g. Plates 3' and 4'' *contactum* Fig 5h. Plates 3' and 4'' *remotum* (after Lefèvre 1932).

studies add credence to the separation of the Umbonatum group from *Peridinium*.

Parvodinium Carty genus novum

Dinoflagellatum aquae dulcis, ovatae ad quinqueangulatus, theca tenue, ordinatione tabulari Po, 4', 2a, 7', C6, S5, 5'', 2''', chromatophoris aureis, epitheca hypothecae superantia, cingulum latum.

Freshwater dinoflagellate, small, ovoid to pentagonal cell, plates thin, plate pattern: apical pore, pore plate, canal plate, 4', 2a, 7'', C6, S5, 5'', 2''', most photosynthetic with yellow-gold plastids, cingulum is wide, sub-median and the hypotheca is smaller than the epitheca. Most species the sulcus enters the epitheca and spreads to the antapex; 3' and 4'' plates may be in *conjunctum*, *contactum* or *remotum* positions.

Type species: *Parvodinium umbonatum* (Stein) Carty comb. nov.
Etymology: *parvo* (L) small, *din* whirling

Parvodinium africanum (Lemmermann) Carty comb. nov.
Basionym: *Peridinium africanum* Lemmermann ex West 1907 J. Linn. Soc. Bot. 38:188 Pl 9 1a-e.

Parvodinium belizensis (Carty) Carty comb. nov.
Basionym: *Peridinium belizensis* Carty ex Carty and Wujek 2003. Carib. J. Sci. 39:137, Fig 14.

Parvodinium centenniale (Playfair) Carty comb. nov.
Basionym: *Peridinium umbonatum* var *centenniale* Playfair 1919. Proc. Linn. Soc. N.S.W. 44:806 Text fig 14.

Parvodinium deflandrei (Lefèvre) Carty comb. nov.
Basionym: *Peridinium deflandrei* Lefèvre 1927. Bull. Mus. Hist. Nat. Paris 33:121

Parvodinium goslaviense (Wołoszyńska) Carty comb. nov.
Basionym: *Peridinium goslaviense* Wołoszyńska 1916. Bull. Acad. Sci. Cracovie Sér. B. p267 Taf 10, Fig 18-24.

Parvodinium inconspicuum (Lemmermann) Carty comb. nov.
Basionym: *Peridinium inconspicuum* Lemmermann 1899. Abh. Nat. ver. Bremen, XVI p350

Parvodinium lubieniense (Wołoszyńska) Carty comb. nov.
Basionym: *Peridinium lubieniense* Wołoszyńska 1916 Bull Acad. Sci. Cracovie Sér. B p272, Taf 12, Fig 21-24.

Parvodinium morzinense (Lefèvre) Carty comb. nov.
Basionym: *Peridinium morzinense* Lefèvre 1928. Annales de Protistol., I. p137
Peridinium elegans Lefèvre 1925 Rev. Algal. 2:332-333.

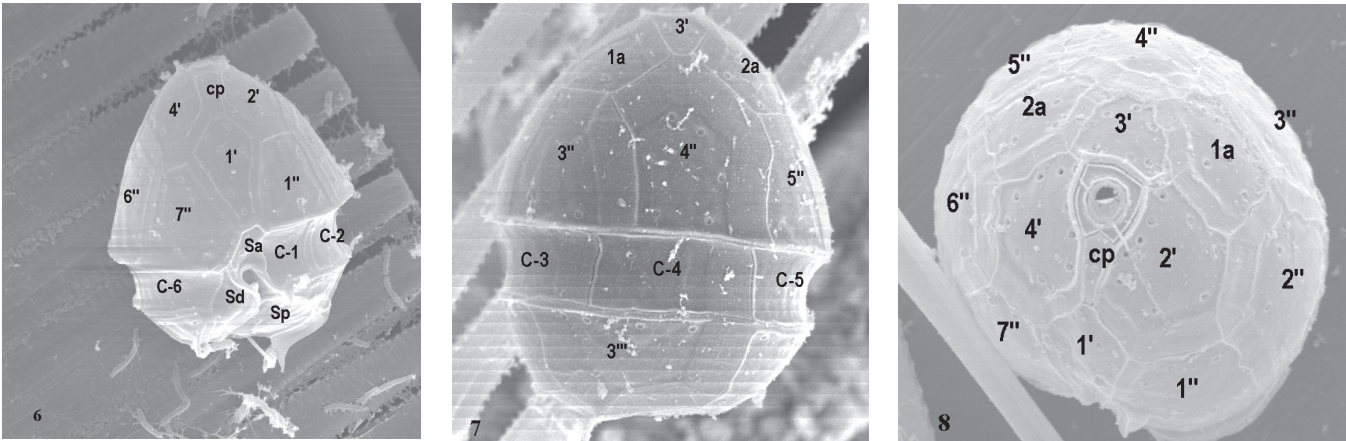
Parvodinium pusillum (Pénard) Carty comb. nov.
Basionym: *Glenodinium pusillum* Penard 1891. Bull. trav. Soc. Bot. Genève VI p52-53 Pl IV Figs 1-4.

Parvodinium umbonatum (Stein) Carty comb. nov.
Basionym: *Peridinium umbonatum* Stein 1883 Organ. Infus. III Pl XII Figs 1-8

Key to the species of *Parvodinium*

- 1a. Cell lacking plastids,
single slender antapical spine
- P. goslaviense*
- 1b. Cell with plastids
- 2

TABLE 1		
Differences between <i>Peridinium cinctum</i> and <i>Parvodinium umbonatum</i>		
Feature	<i>Peridinium cinctum</i>	<i>Parvodinium umbonatum</i>
# apical intercalary plates	3	2
# cingular plates	5	6
Size – length	40-64µm	16-28µm
Size – width	33-58µm	12-26µm
Apical pore	no	yes
Hypothecal spines	no	sometimes
Sulcus in hypotheca	parallel sides	widely spreading



FIGURES 6-8. Scanning electron micrographs of *P. umbonatum*. Fig. 6. Ventral view, plates numbered. Fig. 7. Dorsal view. Fig. 8. Apical view, cp = canal plate.

2a. Epitheca hemispherical, apical pore off-center	<i>P. centenniale</i>
2b. Epitheca angular, pore central, cingulum median	3
2c. Epitheca rounded, pore central	5
3a. Cell with 2 prominent hypothecal spines	<i>P. deflandrei</i>
3b. Cell with small spines or none	4
4a. Small stout spine(s) on hypotheca	<i>P. africanum</i>
4b. Small spines, if any	<i>P. inconspicuum</i>
5a. Plate margins curved	<i>P. morzinense</i>
5b. Plate margins straight	6
6a. Sulcus expanding to antapex, epitheca > hypotheca	<i>P. umbonatum</i>
6b. Sulcal margins parallel or little expanded	7
7a. Antapical plates unequal	<i>P. belizensis</i>
7b. Antapical plates equal in size	8
8a. Epitheca > hypotheca, 13-20µm long	<i>P. pusillum</i>
8b. Epitheca ≈ hypotheca, 35-45 µm long	<i>P. lubieniense</i>

Most of the other groups currently in *Peridinium* also differ morphologically from the Cinctum group, however, most have three intercalary plates. The Palatinum Group (Lefèvre 1932), including *P. palatinum* and *P. pseudolaevae*, was placed in *Cleistoperidinium* with the Cinctum Group since it lacked an apical pore, but is a separate group since it has two apical intercalary plates. At this time I am not removing these species into *Parvoperidinium* since LSU rDNA closely linked *P. cinctum* and *P. pseudolaevae* (Daugbjerg and others 2000).

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